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Hazardous Waste Destruction

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16. ABSTRACT

This paper profiles the current status of hazardous waste thermal destruction in the United States, including facilities and wastes typically handled. The results of extensive EPA-sponsored performance tests are presented for incinerators, industrial boilers, and industrial process kilns. Other aspects of thermal destruction are also addressed, including waste incinerability ranking methods, emissions of potentially hazardous products of incomplete combustion, and current and future thermal destruction capacity.

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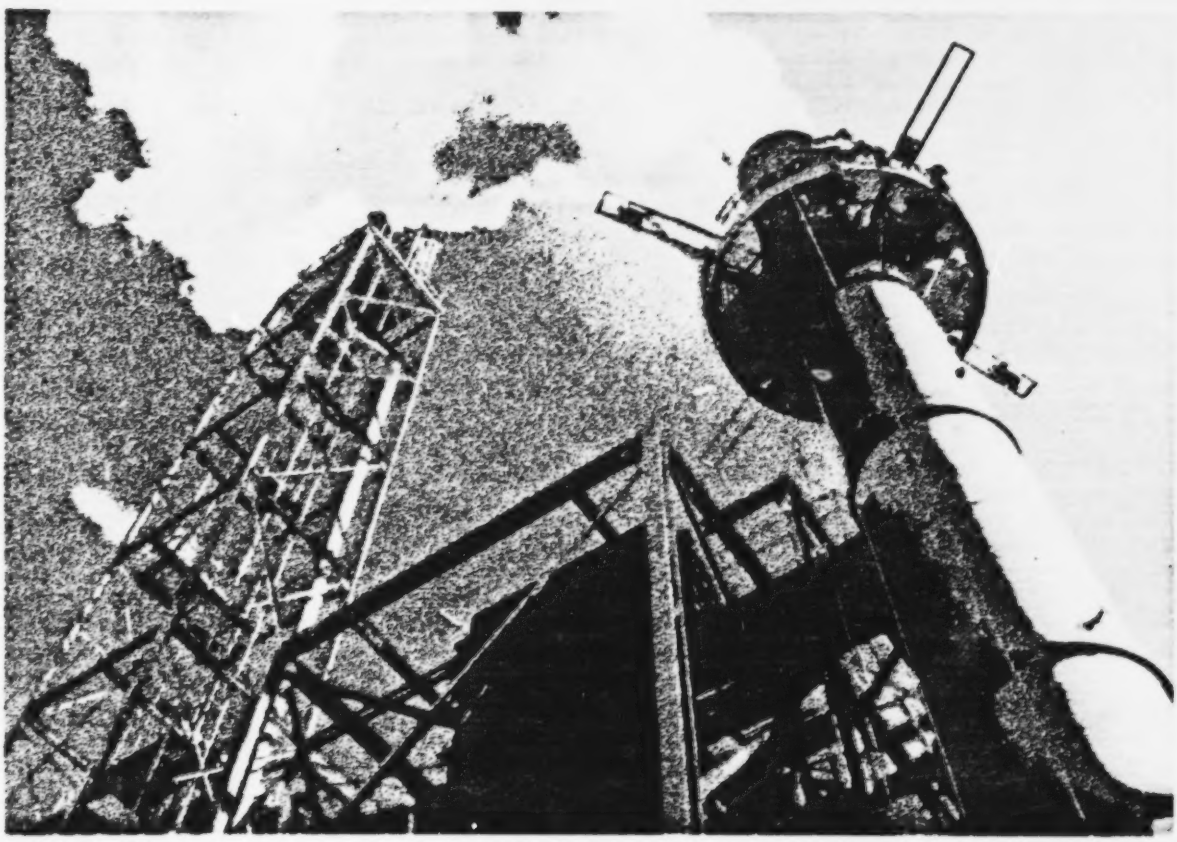
Hazardous waste destruction

Thermal techniques will be increasingly used as legal restrictions on land disposal take effect



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The thermal destruction of hazardous waste involves the controlled exposure of waste to high temperatures (usually 900 °C or greater) in an oxidizing environment. Thermal destruction processes include thermal oxidation, starved-air, or pyrolytic incineration systems; high-temperature industrial processors such as boilers, cement kilns, and industrial furnaces in which hazardous waste is burned as a fuel; and various emerging high-temperature processes such as molten salt or plasma or electric furnaces.

Properly designed and operated thermal destruction systems offer the prospect of destroying the hazardous organic components of waste streams and reducing waste volume. In some instances, these systems can recover energy or materials such as hydrochloric or sulfuric acid. As a result, thermal destruction systems have become recognized over the past decade as an increasingly desirable alternative to the more traditional methods of disposing of hazardous wastes in landfills, lagoons, and injection wells.

The improper design, operation, or use of such systems, however, may pose a threat to public health through emissions of potentially hazardous components of the wastes or their combustion byproducts. The recognition of the inherent environmental advantages of the thermal destruction of waste, balanced against the potential problems of improper practice, led EPA to develop performance standards and permit requirements for thermal destruction systems under the terms of the Resource Conservation and Recovery Act of 1976 (RCRA). Incinerator

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standards have been in place since June 1982 (*1*) and more are currently under development for the disposal of hazardous wastes in industrial processes.

Thermal destruction is expected to gain greater acceptance as EPA responds to its congressional mandate to restrict land disposal of many hazardous wastes. It is also seen as a way of cleaning up abandoned and uncontrolled disposal sites as required by the terms of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA, or Superfund).

Current practice

The most recent comprehensive data on the practices of thermal destruction of hazardous wastes come from surveys of industrial activity conducted by EPA in 1981 (*2*). It is estimated that the United States generated 264 million metric tons (mt) of waste that year, a large portion of which consisted of nonhazardous materials (water) contaminated with smaller amounts of hazardous materials (*2*). More than 5.5 mt was thermally destroyed, 1.7 mt was disposed of in 240 incineration facilities, and 3.8 mt was disposed of in 1300 industrial boilers and furnaces. EPA estimates that as much as 25 mt of the waste generated in 1981 could have been destroyed thermally (*3*).

Hazardous waste incineration practice is more extensively documented than is waste disposal in industrial boilers and furnaces. Incinerators have been the subject of EPA research for nearly 12 years. Regulation, notification, and permit requirements also have produced a large amount of information on incinerators. The practice of using wastes as fuel in industrial boilers and process furnaces will not be fully regulated until late 1986.

In the United States, the incineration technique most commonly used in 1981 was liquid injection (*4*). Liquid incinerators, which are most frequently used to dispose of waste at the site of generation, are employed almost exclusively to destroy pumpable liquid waste. They are usually simple refractory-lined cylinders (either horizontal or vertical) equipped with one or more waste burners. Liquid wastes are injected through the burner, atomized to fine droplets, and burned in suspension. Auxiliary fuel burners and separate waste injection nozzles can be oriented for axial, radial, or tangential firing.

Fixed-hearth incinerators, including excess-air and starved-air or pyrolytic incinerators, are the second most common technology for hazardous waste incineration. Starved-air incinerators, which were first marketed in the early 1960s, have seen rapid growth in use, particularly for the on-site disposal of solid wastes.

Hazardous waste incineration practices as of 1981

Ownership
80% private
20% commercial and military

Waste
77% of facilities handle on-site wastes only
79% of units handle liquids only
11% of units handle bulk wastes (solids and liquids)
10% of units handle special-purpose wastes, such as explosive wastes

Equipment
48% are liquid injection units
19% are fixed-hearth units
6% are rotary kiln or combination units
27% are other (weapons decommissioning or fluidized-bed combustion)
45% have air pollution control systems
22% employ heat recovery

Operations
Median: 1800 °F at 2 s residence time (gas)
Range: 1200–2300 °F; 0.1–6.5 s residence time; most operate on an intermittent schedule

Capacity
Median: liquids, 150 gal/h; solids, 650 lb/h
Range: 0.3 – 142 × 10^6 = Btu/h

Manufacturing
57 companies actively market incinerators
28 companies have sold units
Most units have been installed since 1970
32–40 units are under construction

Starved-air incinerators typically involve two-stage combustion processes by which liquid or solid waste is fed into a primary chamber operated at 50–80% of the stoichiometric air requirement. Vaporized and partially destroyed combustion products are then directed to an afterburner where excess air is added to complete the destruction, usually at a higher temperature than that in the primary chamber.

Rotary kiln incinerators are the third most common incinerator design. They are the most versatile incinerators in that they can destroy solid wastes, slurries, and containerized wastes in addition to liquids. These units are therefore most frequently incorporated into commercial off-site incineration facility designs. The waste is volatilized and partially destroyed in the rotating kiln, a cylindrical refractory-lined shell mounted on a slight incline. Combustion gases then pass through a high-temperature afterburner to complete the destruction process.

The typical air pollution control systems for hazardous waste incinerators include a combustion gas quench, a venturi scrubber (for particulate control), a packed-bed or tray tower acid gas adsorber for acid gas removal, and a mist eliminator. It is interesting to note, however, that more than half of the incinerators in 1981 used no air pollution control systems at all. Perhaps this was because these facilities handled low-ash, low-halogen-content liquid waste streams for which such control measures are not usually necessary.

Many wastes unidentified

There is little precise information on the exact kinds of waste going to thermal destruction facilities. Many facilities operate intermittently and handle mixtures of wastes that are difficult to describe in terms of EPA standard waste codes. A 1983 EPA study examined data on 413 waste streams going to 204 of the 240 incineration facilities in the United States (*5*). The major waste streams incinerated were spent, nonhalogenated solvents (EPA waste code F003) and corrosive and reactive wastes contaminated with organics (EPA waste codes D002 and D003). These materials accounted for 44% of the waste incinerated. Other important wastes included hydrocyanic acid (P063), acrylonitrile bottoms (K011), and contaminated water (D001).

Hazardous wastes also are burned as fuels in many industrial applications. In 1981 such practices disposed of more than twice the amount of waste that was incinerated without being used as fuel. Hazardous waste is burned as fuel in industrial boilers, cement kilns, iron-making furnaces, and lightweight aggregate and asphalt plants. The principal attractions of this approach consist of cost savings in fuel, waste transportation, and disposal.

Versatile rotary kiln incinerators destroy many varieties of waste

The most recent source of information on waste fuel use in industrial processes was compiled for EPA in 1984 (*6*). The study presents results of a national questionnaire on waste fuel and waste oil use in 1983. It reveals that more than 1300 facilities used hazardous-waste-derived fuels (HWDF) that year, accounting for a total of 230 million gal.

The chemical industry (Standard Industrial Classification [SIC] 28) accounted for 67% of this fuel and waste oil use, although it operated only 12.4% of the facilities using HWDF. Other industries included SIC 26 (paper), SIC 29 (petroleum), SIC 32 (stone, clay, glass, concrete), and SIC 33 (primary metals). Sixty-nine percent of the waste was burned in large quantities by facilities that make up only 1.6% of the 1300 facilities. These included facilities with medium and large industrial boilers, cement and aggregate kilns, and iron-making furnaces.

Although data specific to the individual waste codes are not readily available, recent information shows that in 1983, 30% consisted of organic solvents and 45% was made up of other hazardous organics (*6*). Most of this waste was generated on site, and 74% of the balance arrived directly from offsite generators rather than through intermediaries.

Thermal destruction devices

Until recently, only limited data were available on the performance of thermal destruction devices in destroying waste and curbing pollutant emissions. EPA and others conducted performance tests during the 1970s that used a variety of trace organic pollutant sampling and analysis techniques. These techniques often were geared to measuring overall combustion and destruction efficiencies rather than the ability of an incinerator to comply with the rigid performance requirements mandated by RCRA today (*7*).

Since 1981, EPA has conducted a program of performance testing at thermal destruction facilities. The program was designed to provide information on the ability of processes to destroy hazardous wastes to the degree required by the 1982 incinerator performance standards (*1*). Before obtaining operating permits, operators must demonstrate that the facilities can meet the following requirements:

- at least 99.99% destruction and removal efficiency (DRE) for each principal organic hazardous constituent (POHC) in the waste feed;
- at least 99% removal of hydrogen chloride from the exhaust gas if hydrogen chloride stack emissions are greater than 4 lb/h; and
- particulate emissions not exceeding 0.08 grains/dry standard cubic foot (dscf), corrected to 7% oxygen in the stack gas.

EPA's performance evaluation program encompassed the testing of many commercial and industrial thermal destruction devices and designs, sizes of facilities, and varieties of wastes. Testing procedures used standard EPA sampling and analysis methods, including the volatile organic sampling train (VOST), a sampling technique specially developed for detecting low concentrations of volatile POHCs in emissions (*8*, *9*).

Test protocols included waste and base fuel analysis for hazardous constituents; stack gas sampling and analysis for hazardous constituents, particulate matter, hydrogen chloride, metals, and criteria pollutants (NO_x, SO_2); ash and scrubber water analysis; and appropriate process monitoring and control data (CO, CO_2, O_2, temperature at critical points, flows, and pressures).

The evaluations usually were conducted under operating conditions normally used at the facility; the objective was to determine whether typical performance met incineration emission standards. Normally, operating conditions were not intentionally varied to assess changes in performance. In many tests, however, various compounds, such as carbon tetrachloride, trichloroethylene, and chlorobenzene, were added to the waste feed to facilitate comparison of performance results among facilities. In cases of industrial processes using a hazardous waste as supplemental fuel, baseline tests also were conducted to determine background levels of emissions with only the conventional fuel.

Tables 1–3 describe the facilities and wastes studied by the test program and summarize destruction and emission control performance data (*10–13*). These test results are significant because they reveal that a well-operated incinerator, industrial boiler, or process kiln can achieve a DRE of 99.99%. All of the incinerators tested achieved this level of performance for candidate POHC compounds in concentrations >1000 ppm in the waste feed. Candidate POHC compounds at concentrations <500 ppm frequently were not destroyed to the extent of 99.99%.

This phenomenon, which also was observed in tests of other thermal destruction devices, was unexpected. A number of possible explanations have been advanced. At the low stack emission concentrations necessary to demonstrate 99.99% DRE for <500 ppm POHCs, sampling and analysis techniques may be limiting factors. Also at these low emission levels, sufficient amounts of POHC candidate compounds may actually be formed as incomplete combustion or recombination byproducts of other materials in the wastes to cause the DRE to fall below 99.99%.

EPA is conducting research to assess this concentration phenomenon. From a regulatory standpoint, however, it is not currently perceived as a problem, because few if any of the low-concentration compounds in the wastes identified in the EPA test program actually would have been selected as POHCs in trial burns had existing EPA guidelines on POHC selection been employed.

The waste at each site typically contained many hazardous compounds that were candidates for being selected as POHCs. All of the compounds that could be measured were measured, and DRE values were calculated. Under current EPA permit guidelines, however, only two or three compounds, usually the highest in concentration, were selected as POHCs to measure DRE attainment.

Industrial boilers, particularly the larger water tube units, were acceptable devices for waste destruction. Cement kilns, lime kilns, and lightweight aggregate kilns with adequate combustion

TABLE 1
Incineration facilities tested

Facility	Control device	Waste	DRE[a] (number of nines)[b]	HCl control (average)	Average particulate emissions (g/dscf)
Commercial rotary kiln–liquid incinerator (87 million Btu/h)	Packed-tower adsorber; ionizing wet scrubber	Drummed, aqueous, liquid organic waste with carbon tetrachloride, TCE[c], perchloroethylene, toluene, phenol	5.3	99.4%	0.67
Commercial fixed-hearth, two-stage incinerator (25 million Btu/h)	Electrified gravel bed filter; packed-tower adsorber	Liquid organic and aqueous waste with chloroform, carbon tetrachloride, TCE, toluene, perchloroethylene	4.4	98.3%	0.178
On-site two-stage liquid incinerator (6 million Btu/h)	Packed-tower adsorber	Liquid organic waste with carbon tetrachloride, dichlorobenzene, TCE, chlorobenzene, chloromethane, aniline, phosgene	4.4	99.7%	0.027
Commercial fixed-hearth two-stage incinerator (2 million Btu/h)	None	Liquid organic waste with TCE, carbon tetrachloride, toluene, chlorobenzene	4.7	>4 lb/h[d]	0.089
On-site liquid injection incinerator (4.8 million Btu/h)	None	Liquid organic waste with aniline, diphenylamine, mono- and dinitrobenzene	6.7	>4 lb/h[d]	0.092
Commercial fixed-hearth two-stage incinerator (10 million Btu/h)	None	Aqueous and organic liquid waste with carbon tetrachloride, TCE, benzene, phenol, perchloroethylene, toluene, methylethyl ketone	4.8	>4 lb/h[d]	0.40
On-site rotary kiln with liquid injection (35 million Btu/h)	Venturi scrubber with cyclone separators and packed-tower adsorbers	Liquid organic, paint waste and filter cakes with methylene chloride, chloroform, benzyl chloride, hexachloroethane, toluene, TCE, carbon tetrachloride	5.3	99.9%	0.01
Commercial fixed-hearth two-stage incinerator (75 million Btu/h)	Venturi scrubber	Aqueous and organic liquids and solid waste with methylene chloride, chloroform, carbon tetrachloride, hexachlorocyclopentadiene, toluene, benzene, TCE	4.6	98.3%	0.075

[a]Destruction and removal efficiency (mass weighted average for all POHCs >100 ppm in waste feed). [b]For example, 99.995% DRE = 4.5 nines. [c]TCE = trichloroethylene. [d]No HCl control device; waste is low in total organic chlorine content.

TABLE 2
Industrial boiler facilities tested

Facility	Control device	Waste	DRE[a] (number of nines)[b]
Watertube stoker, wood-fired (10 million Btu/h)	Multiclone	Creosote sludge with phenol, pentachlorophenol, and naphthalene	3.8
Packaged firetube, gas-fired (8.5 million Btu/h)	None	Alkyd wastewater with toluene	4.1
Field-erected watertube, gas- or oil-fired (230 million Btu/h)	None	Phenol waste	5.6
Converted stoker, oil-fired (90 million Btu/h)	None	Methanol, toluene, and chlorinated organics including perchloroethylene	4.8
Packaged watertube, oil-fired (110 million Btu/h)	None	Methyl methacrylate byproducts with carbon tetrachloride, chlorobenzene, and TCE[c]	4.5
Converted watertube, oil-fired (60 million Btu/h)	None	Paint solvents with carbon tetrachloride, TCE, toluene, and chlorobenzene	3.8
Modified firetube, waste-fired (40 million Btu/h)	Two scrubbers in series	Highly chlorinated organics including carbon tetrachloride	4.8
Tangentially fired watertube, coal-fired (250 million Btu/h)	Electrostatic precipitator	Methyl acetate, carbon tetrachloride, trichloroethane, chlorobenzene	4.1
Packaged watertube, gas-fired (62 million Btu/h)	None	Aniline waste with nitrobenzene, carbon tetrachloride, TCE, benzene, toluene	4.8
Packaged watertube, waste-fired (10 million Btu/h)	None	Toluene, chlorinated organics including carbon tetrachloride and TCE	5.0
Packaged watertube, oil-fired (60 million Btu/h)	None	Blended waste with light oil and carbon tetrachloride, benzene, TCE, and toluene	5.7

[a]Destruction and removal efficiency (mass weighted average for all POHCs >100 ppm in waste feed). [b]For example, 99.995% DRE = 4.5 nines. [c]TCE = trichloroethylene.

TABLE 3
Industrial kiln facilities tested

Facility	Control device	Waste	DRE[a] (number of nines)[b]
Wet process cement kiln; nonatomized waste; 140 million Btu/h, oil-fired	Fabric filter	Waste liquids including methylene chloride, chloroform, carbon tetrachloride	2.8
Wet process cement kiln; atomized waste; 170 million Btu/h, coal-fired	Electrostatic precipitator	Waste liquids including methylene chloride, MEK[c], trichloroethane, toluene, Freon 113	4.2
Dry process cement kiln; nonatomized waste; 228 million Btu/h, coal- or coke-fired	Electrostatic precipitator	Waste liquids including methylene chloride, Freon 113, MEK, toluene, trichloroethane	4.1
Dry process cement kiln; atomized waste; 300 million Btu/h, coal- or coke-fired	Fabric filter	Waste liquids including trichloroethane, trimethylbenzene, xylene, methylene chloride	>4
Lime kiln; atomized waste; 50 million Btu/h, coke- or gas-fired	Fabric filter	Waste liquids including methylene chloride, MEK, TCE[d]	4.7
Shale aggregate kiln; atomized waste; 35 million Btu/h, coal-fired	Scrubber	Waste liquids including perchloroethylene, MEK	>5
Clay aggregate kiln, 20 million Btu/h, coal-fired	Scrubbers	Waste liquids including MEK, perchloroethylene, toluene	4.8
Clay products kiln; atomized waste; 37.5 million Btu/h, oil-fired	Fabric filter	Waste liquids, waste oil, Freon 113, perchloroethylene, carbon tetrachloride, benzene, TCE, toluene	3.5

[a]Destruction and removal efficiency (mass weighted average for all POHCs >100 ppm in waste feed). [b]For example, 99.995% DRE = 4.5 nines. [c]MEK = methylethylketone. [d]TCE = trichloroethylene.

control and waste atomization all met or exceeded the 99.99% DRE requirement. It is also important to note that for all of the incinerators and industrial processes tested, the DREs observed have been attributable to actual destruction rather than to removal or capture of hazardous organic compounds. Ash, scrubber water, and air pollution control device residues were typically below detection limits for POHCs and organics in general.

All incinerators and industrial process kilns tested met or approached the RCRA removal standard for hydrogen chloride. Industrial boilers typically have no existing controls for hydrogen chloride, but none exceeded the 4 lb/h emission standard, because wastes with low net chlorine content were burned. In some cases the kilns failed by very small margins to meet the standard for hydrogen chloride. Minor changes in their operation, however, could readily overcome that problem.

Achieving the particulate emission standard was a problem with a number of the incinerators tested (*10–13*). Four of the eight units failed to meet the RCRA standard. Two of those facilities were marginally above the emission limit and probably could have met the standard with minor operating adjustments. The remaining two facilities appeared to need significant design and operating changes. This general trend is consistent with the results of RCRA permit trial burns conducted for other incineration facilities over the past two years.

No significant changes in particulate emissions were observed for industrial boilers and some of the industrial process kilns at which waste fuels were burned. Some increased emissions were observed in kilns employing electrostatic precipitators for particulate control. These increases were attributed to changes in the electrical resistivity of the particles caused by the presence of increased chloride levels. Adjustments in precipitator operation should correct this shortcoming in most cases.

Analysis of the pooled data from the incinerator test program revealed that there was no absolute level of mean combustion temperature, mean gas-phase residence time, or carbon monoxide emission concentration that could be correlated with the achievement of 99.99% DRE. Residence times ranged from 0.1 s to 6.5 s in the facilities tested. Temperatures ranged from 648 °C to 1450 °C. Carbon monoxide levels were as high as 600 ppm, but at most plants they ranged from 5 ppm to 15 ppm.

The relationships between DRE and these characteristics are, in all likelihood, specific to the facility in question. Waste characteristics, waste atomization, and mixing in the combustion chamber are equally important to achieving high DRE. Timing, funding, and facility constraints did not allow the collection of enough performance data under varying conditions at each site tested to quantify these relationships. EPA continues to obtain test results and information from trial burns and from tests at EPA pilot scale research facilities. This information is added to the data base in an effort to improve the predictability of DRE of incineration processes.

It is not yet possible to specify absolute levels of process operating parameters that will guarantee in advance that an incinerator will meet the 99.99% DRE standard for a particular waste. Therefore, efforts are being made to identify easily monitored process emissions which may be real-time indicators of the onset of a process's failure to achieve acceptable DRE. In other words, continuous monitoring for specific absolute levels of emissions of carbon monoxide, oxygen, and total halogenated organic carbon cannot guarantee that a 99.99% DRE is being attained.

The objective of EPA's research is to identify and quantify engineering relationships between potential incinerator process failures, such as inadequate waste atomization and overfeeding, and process performance indicator emissions, such as carbon monoxide, total unburned hydrocarbon, oxygen, and emissions of potentially difficult-to-incinerate tracer compounds (sulfur hexafluoride, various freons) that could be "spiked" into the incinerator feed. Such relationships could be quantified during trial burns at each facility and could be used for process control by operators and for compliance assessment by regulators.

This research is being conducted in bench scale and pilot scale thermal destruction research facilities in Cincinnati, Ohio; Research Triangle Park, N.C.; and at EPA's Combustion Research Facility near Pine Bluff, Ark. Additional full-scale facility testing is being conducted to assess non-steady-state or upset combustion conditions on DRE and indicator emissions (rapid,

usually short-lived departures from normal operation, such as temperature increases or decreases and increases in carbon monoxide emissions).

Incinerability

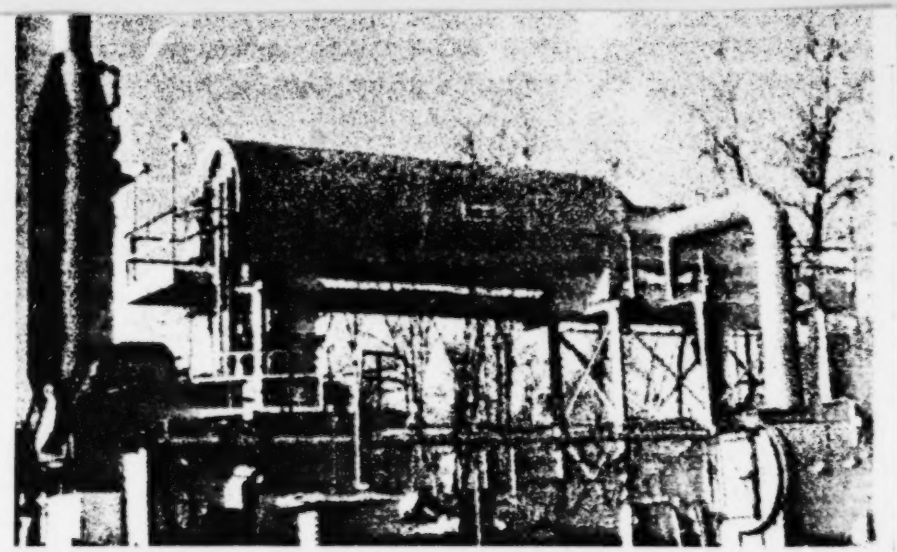
EPA researchers have also examined the test data to try to define DRE values for POHCs as a function of the various approaches that have been suggested for determining a POHC's incinerability or its difficulty in being thermally destroyed (*14*). EPA guidelines for conducting a trial burn suggest that a compound's incinerability and concentration in the waste are important criteria for selecting it as a POHC (*15*).

The various methods that have been considered for the incinerability ranking of hazardous wastes have been a matter of some scientific debate over the past several years. EPA has recommended using a compound's heat of combustion as a criterion. Other suggestions include the use of bond energies derived from theoretical kinetics, autoignition temperatures, and laboratory data on thermal decomposition to approximate compound incinerability. Analysis of pooled field test data indicated that no strong correlation could be found for DRE as opposed to any of the ranking methods. Research data, however, suggest the use of an incinerability ranking based on gas-phase thermal stability data collected in laboratory experiments under oxygen-deficient conditions (*14*).

Comparison of these stability data with appropriate field test data indicates that field thermal stability rankings could be predicted from the laboratory data in 70% of the cases evaluated. Additional research is being conducted to expand the number of compounds for which comparisons can be made.

Incomplete combustion products

The current RCRA standards regulate destruction and removal only for the major hazardous compounds in the waste. Under poor combustion conditions, many compounds may decompose only partially to form products of incomplete combustion (PICs), which are also hazardous compounds of concern if they are emitted. For the purposes of the EPA test program, compounds are considered PICs if they are regulated organic compounds (listed in the *Code of Federal Regulations*, Title 40, Part 261, Appendix VIII, revised July 1, 1985) detected in stack emissions but not present in the waste feed at concentrations > 100 ppm. The PICs most frequently identified in the EPA testing of incinerators and industrial boilers have been benzene, chloroform, and tetrachloroethylene (*11, 16*). As of June 1985, detailed PIC analyses had been completed for three cement kiln tests. The most common PICs identified during the kiln tests were benzene, benzaldehyde, toluene, and various naphthalenes (*12*).



Liquid injection incinerators often are used to dispose of liquid wastes

EPA is conducting research to assess the nature and magnitude of PIC emissions from the thermal destruction of hazardous waste. Current data suggest that for thermal destruction facilities where high degrees of DRE have been achieved for POHCs, PIC emissions are also low and not of environmental concern. Consequently, EPA does not plan to regulate PICs under RCRA. EPA is conducting research, however, to determine whether there are problems with PICs in untested waste–facility combinations not included in the test program or under marginal thermal destruction conditions (for example, the failure to meet DRE standards). Knowledge of the mechanisms of PIC formation and of PIC abatement through the control of combustion conditions is therefore important to EPA.

Thermal destruction prospects

Prospects for the increased use of thermal destruction of hazardous wastes are good. Incineration is a proven, commercially available technology that has been demonstrated to be suitable for handling a wide variety of wastes. Industrial high-temperature processes also can be modified to destroy certain hazardous wastes (particularly combustible liquids) and allow for the recovery of energy.

Thermal destruction is currently used to dispose of only 2% of the 264 mt of hazardous wastes generated annually. Many of the remaining wastes are still directly disposed of on land. However, the recently promulgated Hazardous and Solid Waste Amendments of 1984 (the RCRA amendments), with their sweeping provisions to restrict the land disposal of many wastes, will prompt increased consideration of thermal destruction as an option. Many waste generators already are placing emphasis on this option in the interest of resolving long-term liability issues through destruction rather than through uncertain land-based containment techniques.

It also is virtually certain that increased Superfund cleanup activities will generate wastes and on-site treatment residues that will be managed by thermal destruction. Most of these wastes will be more appropriate for destruction in large commercial incinerators or in multipurpose mobile incinerators, which are now under development for use on site.

For the near future, perhaps the next five years, there appears to be sufficient thermal destruction capacity. An EPA study completed in 1984 estimated that on-site and commercial incineration capacity use is somewhere between 37% and 74% (*17*). Another assessment estimated incinerator capacity use at 47% for 1981.

There also are more than 43,000 industrial boilers in the United States, of sizes and designs that could achieve acceptable waste destruction (*18*). Of this number, 5500 boilers are located in the chemical, petroleum refining, and paper industries. About 70% of the total hazardous waste generated and more than 95% of all potentially combustible hazardous waste could be disposed of in these boilers. Although only 10 industrial process kilns currently are being used to dispose of hazardous waste, the operators of as many as 600 kilns across the United States might consider this option (*18*).

Restriction on land disposal

EPA has estimated the amount of hazardous waste that might be redirected to commercial incineration as a

result of restrictions on disposal in landfills, lagoons, and injection wells (*17*). These restrictions are expected to result in an excess of demand over existing capacity of commercial incineration facilities of 215–306% for liquid wastes alone. Translated into facility capacity, this percentage converts to as many as 26 land-based incinerators (disposing of 20,000 t each), or 10 incinerator ships (50,000 t each). Solid hazardous waste and Superfund cleanup residues would further increase the shortfall.

Although many boiler and kiln facilities could dispose of waste, much that will become available for feeding into these facilities is likely to be increasingly less attractive to their operators. This waste will tend to be much less combustible because it is higher in solid, ash, and water content and therefore more suitable for conventional commercial incineration.

Permitting and siting difficulties are significant impediments to the development of commercial incinerator capacity and to the use of industrial kilns for waste disposal. Consequently, little growth of available commercial incineration capacity may be expected over the short term. A three- to five-year delay is possible before significant new capacity could be available.

Many believe that the use of self-contained mobile incinerators or larger but transportable units is one way of mitigating the public opposition that frequently plagues the construction of permanent centralized incineration facilities. Although a number of mobile systems have been proposed, most are still in development. Little actual field testing has been done beyond that under way on an EPA-owned mobile rotary kiln incinerator (*19*). This unit has been tested for the efficiency of polychlorinated biphenyl and carbon tetrachloride destruction. It is currently being tested for its ability to incinerate dioxin-contaminated soils in Missouri.

More wastes burned

Thermal destruction is an effective and broadly applicable technique for the destruction of organic hazardous wastes. Performance tests conducted by EPA indicate that incinerators and many high-temperature industrial processes are capable of achieving RCRA performance and emissions standards. Although only a small percentage of the hazardous waste managed annually in the United States is currently destroyed thermally, significant increases in the use of these processes is anticipated because of the 1984 RCRA amendments and increased Superfund remedial actions. Permit and siting difficulties may, however, delay the installation of new incinerator capacity, particularly for commercial facilities.

Test burns of hazardous waste

To determine how well incineration works, EPA has been conducting a series of test burns at its combustion research facility near Pine Bluff, Ark. One objective is to learn how well incineration destroys hazardous waste, especially dioxin-contaminated liquids and leachate sludges. Another is to test the effectiveness of emissions sampling equipment and techniques.

The first test burn, completed last autumn, involved the incineration of 300 gal of wastes from the production of 2,4,5-trichlorophenol and the herbicide 2,4,5-T. These wastes, which were highly contaminated with dioxins, were obtained from a Superfund site near Jacksonville, Ark. Results of preliminary analyses indicate that no dioxins were present in the stack emissions.

EPA plans to conduct similar test burns for residues from a number of Superfund sites in the United States. These tests are expected to begin in April 1986 and will involve

- PCB-contaminated sludges and soils from the Bridgeport Rental and Oil Services site in Bridgeport, N.J.,
- contaminated soils from the Stringfellow Landfill in Riverside County, Calif., and
- dioxin-contaminated soils, stream sediments, sludges, and activated carbon from Love Canal in Niagara Falls, N.Y.

Acknowledgment

This document has been reviewed in accordance with EPA policy and approved for publication. Mention of commercial products does not constitute endorsement or recommendation for use.

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